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TITLE: Sleep and cognitive function in young children.

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INTRODUCTION

The emerging picture from research studies that have attempted to define what 'normal' sleep duration might be for young children is that sleep duration is subject to great variability resulting from biological, environmental and social factors. Parents are concerned about their child's sleep for important reasons, given the wealth of evidence linking sleep with developmental outcomes. Insufficient sleep has a number of daytime consequences, predominately impairment in cognitive function which is more pronounced in younger than older children and is associated with family socio-demographics. Bedtime routines are related to better sleep outcomes which are achieved the more frequently the routine is implemented. When children experience insufficient night-time sleep they may compensate for this through daytime napping; a behaviour which also supports cognitive function and facilitates subject specific learning. Encouraging parents to implement and develop appropriate bedtime routines and helping them to identify cues relating to their child's individual sleep need will contribute to supporting cognitive function and learning.

KEYWORDS

Sleep, Cognitive function, young children, Bedtime routine, Napping

MAIN TEXT

We know that the amount of sleep that children need varies as a function of age, declining as children move from infancy, to pre-school and into early childhood (Galland et al., 2012; Iglowstein et al., 2003), but how much sleep is sufficient, or optimal, at each developmental stage of a child's life is a trickier issue. Should we be thinking in terms of an absolute number of hours, a range, or a particular outcome (e.g. a child who wakes spontaneously following a restful sleep)? A number of research studies have attempted to elucidate what 'normal' sleep duration might be for children from data collected across representative population samples. Iglowstein et al. (2003) aimed to calculate sleep duration at different ages in a sample of Swiss children: 96% of three year old children slept on average between 10.3-14.8 hours over a 24 hour period. Mindell et al. (2010) reported sleep patterns in children aged 0-3 years across 17 (predominately Caucasian or Asian) countries and found the average total daily sleep duration ranged from 11.62 hours in Japan, to 13.31 hours in New Zealand with children in the UK having the third longest daily sleep duration of any country (13:06 hours). Whilst these ranges of sleep duration fall within the daily 11-13 hours recommended by the US National Sleep Foundation, they are indicative of the great variability and difficulty in applying a universal 'sleep target' to young children. Indeed a systematic review by Galland et al. (2012) summarising the data from 34 previous studies of infant and child sleep between birth and 12 years of age found that children between the ages of 2-5 years old slept between 9.9-13.8 hours per day. From these data, Galland et al. were able to calculate the decline of sleep duration with age. Between 1-4 years, sleep duration declined at the rate of 7.8 min per year. Like Mindell et al. (2010), Galland also found that children residing in predominantly Asian countries had shorter sleep (1 hour less over the 0-12 year old age range) compared to those studied in non-Asian countries. The picture emerging from these studies, therefore, is that while researchers can calculate averages for particular age-groups, individual children will be distributed above and below the average value indicating the huge variability in individual sleep duration. For young children, this variability is strongly influenced by a complex interplay of biological processes,

and environmental, behavioural and social factors e.g. daycare schedules, parenting/cultural practices and expectations and routines.

Parents are often concerned about their child's sleep. Across Western cultures, 25% of parents report that their child experiences sleep problems (Owens 2005). Often it's a child's ability (or inability) to return to sleep unaided that plays a major role in whether determining sleep is problematic, with the frequency of night wakings often forming the basis of how parents judge the quality of their child's sleep (Palmstierna, Sepa & Ludvigsson, 2008). Defining a sleep problem or a sleep disorder in children is difficult. Although the general criteria for sleep problems include frequent, severe and chronic symptoms of bedtime resistance and night wakings, it is not clear what is considered 'frequent' and for how long these behaviours need to be exhibited before being considered problematic or a disorder. In addition, as problematic child sleep is typically defined by the child's parents, it is subject to reporting bias as the parents' understanding of a sleep problem is influenced by their beliefs, values and experiences; indeed parents with poor sleep themselves over-report that their child has sleep problems (Rönnlund et al. 2016).

Parents are concerned about their child's sleep for important reasons. There is a wealth of evidence showing how sleep in young children is critical for overall development (e.g. Bates et al. 2002; Valent, Brusaferrro & Barbone 2002; Agras et al. 2004) and is particularly integral to learning. This is because insufficient sleep is associated with a number of daytime consequences, including impairment of normal cognitive function, i.e. reaction time, attention, focus, recall and memory (Diekelmann 2014). Sadeh (2007) summarised that there are two basic underlying mechanisms by which sleep impacts cognitive functioning, learning and behaviour in general. The first relates to the role that sleep plays in how the brain matures, maintains, processes information and consolidates memory and how insufficient sleep prevents/reduces these necessary brain activities. Memory consolidation is a process by which memory storage and retrieval become more efficient and stable post-sleep and is of particular importance when considering sleep as a key component of learning. The second mechanism is related to the reinvigorating role of sleep and how insufficient sleep increases the prevalence of daytime sleepiness and reduces alertness, which in turn leads to compromised cognitive function and behaviour regulation.

It is recognised that the implications of insufficient sleep for cognitive function and learning are more problematic for younger than older children (Curcio, Ferrara & De Gennaro, 2006), and affects those who are socio-economically disadvantaged to a much greater degree (Jones and Balls 2014). It has been hypothesised that differences in sleep parameters among children from higher and lower socio-economic status families are associated with some portion of the attainment gap as children who are disadvantaged experience significantly shorter nighttime sleep (Buckhalt 2011). It is not clear why disadvantaged children achieve a shorter sleep duration (total and nighttime), although it is noted that particular recommended 'sleep hygiene' practices which often comprise a bedtime routine e.g. having regular sleep-wake times, sleeping in a quiet dark room, lack of electronics, promote better quality and longer sleep in children, are less likely to be implemented by parents who are disadvantaged (Hale et al. 2009). Hale et al. (2009) investigated whether child and family characteristics were associated with the presence, time and consistency of bedtime routines - where a parent engages their child in the same activities, in the same order before turning the lights off for sleep - among low income families. Here, 80% of families reported having a bedtime routine but its implementation decreased with presence of poverty, low maternal education and increased household size. Children who experience daily routines in general are more likely to live in less stressful environments (El-Sheikh et al. 2007) and a consistent daily bedtime routine is frequently recommended as part of a healthy

habit for preschool children. Bedtime routines have been associated with less sleep disruption and a greater total sleep duration among young children. The benefits of a bedtime routine for sleep in young children are dose-dependent; better sleep outcomes are associated with the more nights a week that a routine is implemented (Mindell et al. 2015). In Mindell et al.'s (2015) study, parents of pre-schoolers with a current bedtime routine were less likely to report current daytime behaviour problems, including problems of hyperactivity, attention deficit, or difficult behaviours, than those without a bedtime routine.

When children experience insufficient nighttime sleep they may compensate for this through daytime napping. By the age of 3 years old, there is much individual variability in napping behaviour whereby some children do not nap at all, some do infrequently, whilst others nap for over 2 hours each day. Iglowstein et al. (2003) reported that 50% of 3-year-old Swiss children did not nap during the day, whilst for 96% of those who did nap, daily duration ranged from 0.8-2.6 hours. Ward et al. (2008b) and Weissbluth (1995) examined sleep and napping behaviours in young children, and both concluded that the majority of children nap when given the opportunity and that daytime nap could be of benefit to most preschool children. The transition to daycare has been found to be associated with a reduction in total weekday sleep due to the omission of daytime napping (Cairns and Harsh 2013), however napping is often perceived negatively by parents of preschool children in the UK (Jones and Ball 2014). This is because it can reduce the build-up of 'sleep pressure' - the need for sleep, determined by amount of time that has elapsed since the last adequate sleep episode and driven by internal physiological processes (see Jennia and LeBourgeois 2006) - during the day, and therefore reduces the propensity for sleep in the evening. Further investigation is required to learn about the functions of napping in young children and the potential consequences of consolidated versus combined nighttime and daytime sleep. There is some suggestion that nighttime sleep and daytime naps have different physiological functions, whereby nighttime sleep has complex biological, psychosocial and restorative functions and daytime naps reduce psychosocial stress, and increase attention span and alertness (Bell & Zimmerman, 2010; Ward et al., 2008a).

Daytime napping, following a period of learning, also plays a significant role in learning via the strengthening and consolidating memory as it can stabilise recently learned material, making it resistant to the normal loss that occurs over the day (Ellenbogen et al. 2007). This is particularly important for learning during early childhood when short term memory stores are limited, and memory consolidation needs to take place frequently. For infants, naps are necessary for sustaining new learning. At 15-months old, a child can generalise a linguistic pattern within 24-hours if they have napped within 4 hours of the learning period, but not if they are kept awake (Hupbach et al., 2009). Among pre-schoolers, Kurdziel, Duclos and Spencer (2013) demonstrated a clear nap benefit on memory retention in a laboratory setting. The introduction of an afternoon nap post-learning increased memory by 10% - assessed immediately post nap and the following day - in comparison to significant performance losses among the nap deprived. Three year olds are also more likely to retain novel new verbs following a daytime nap, even if they no longer nap on a regular basis. Sandoval, Leclerc and Gomez (2017) explained that this generalisation of learning did not occur among those children who did not received a nap following the learning activity. Lengthening sleep duration via napping appears to not only have the potential to positively impact cognitive function, but also indirectly via improved behavioural (i.e. children who have longer total sleep durations are less likely to experience behavioural problems in both class and home environments (Bates et al. 2002)) and health (i.e. children who have longer total sleep durations are less likely to experience ill-health and obesity (Agras et al. 2004)).

Sleep, then, appears to play an important part in cognitive function for young children.

Sleep needs are as individual as other aspects of a child's biology (e.g. growth rate, stamina) and individual sleep requirements will vary from child to child. However, how much sleep a child achieves is heavily influenced by a complex interplay of biological, environmental and social factors, particularly parenting. We should take our cues as to whether a child is obtaining insufficient sleep from their daytime behaviour, rather than an arbitrary sleep target. If children are building up sleep pressure that is not being dissipated by restful night-time sleep they will lose concentration, become frustrated, appear drowsy, and fall asleep quickly when given the opportunity. Provision of the opportunity to nap during playtime or after school may be a particularly helpful practice to remedy negative daytime behaviours and also support learning processes. Within the home environment supporting parents in developing an appropriate bedtime routine at a time when their child is naturally feeling sleepy (experiencing the build-up of sleep pressure) is important. These routines should prioritise their child's night-time sleep needs and include appropriate bed-times and restful sleep environments that minimise disturbances by other members of the household. If a child wakes happily, and is alert in the morning they are probably achieving sufficient night-time sleep and this will be reflected in their ability to function and learn.

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